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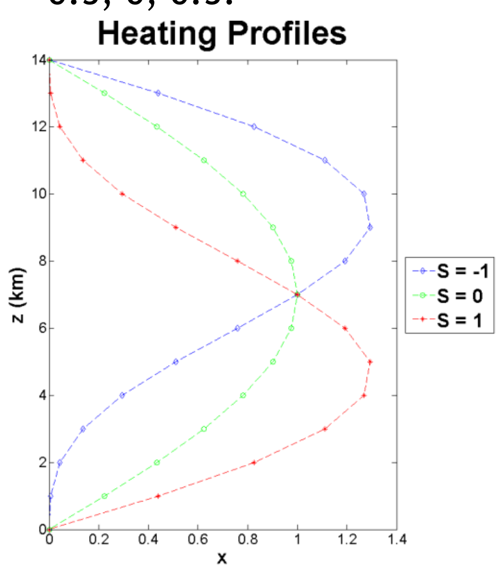
MPO 663
**Homework #2, Part 2**

**5.** Now **construct and visualize (by computer)** the balanced line vortex created by *2-vertical-mode* heating at the origin. That is, take q = Q(x=0, in distant past) [$\sin(m_1 z)$ – S $\sin(m_2 z)$], where $m_1 = \pi/14$km and $m_1 = 2\pi/14$km. [S may be viewed as a “stratiform fraction” when positive, or “shallow convection fraction” when negative.] Use meshgrid (in Matlab) or findgen (in IDL) to build 2D x and z arrays, and then just use the formulas from above.

Because the equation set is linear, you can evaluate the formulas for v for the two values of m separately, and then construct the S-weighted sum of these two arrays. Also, because the equations are linear, the absolute magnitude of the total solution is arbitrary. Take N = $2\pi/600$s (a typical tropospheric stratification).

a. **Plot the heating profiles** in the domain $z \in [0,14\text{km}]$ for S = -0.5, 0, 0.5.



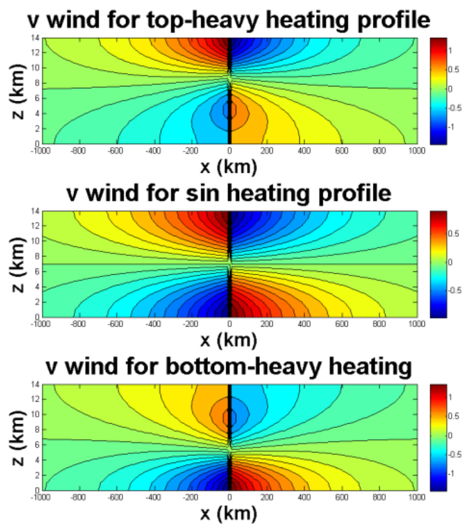

**Verify** that the total heat added (vertical integral) is the same in all cases.
The vertical integral is the same (8,875) in all cases.

b. **Calculate the Rossby radii** for the two vertical modes.

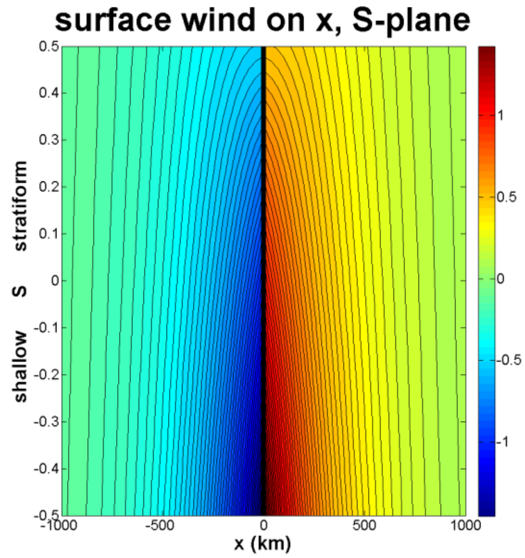
$$L_{R1} = \frac{c_1}{f} = \frac{N}{fm_1} = \frac{\frac{2\pi}{600}\,s^{-1}}{(10^{-4}\,s^{-1})\left(\frac{\pi}{14}\,km^{-1}\right)} \approx 466\ km$$

$$L_{R2} = \frac{N}{fm_2} = \frac{\frac{2\pi}{600}\,s^{-1}}{(10^{-4}\,s^{-1})\left(\frac{2\pi}{14}\,km^{-1}\right)} \approx 233\ km$$

c. Construct numerical arrays containing vortex structures for each vertical mode in an x domain about 2-3 of the larger Rossby radius in width, using your answer to part 4. **Contour the tangential (v) wind** in the x-z plane for S = -0.5, 0, 0.5.

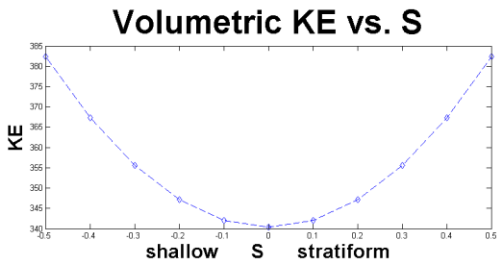


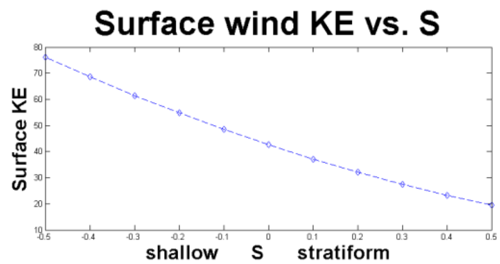
d. **Plot** the domain-integrated KE versus S for values of S in [-0.5,0.5]. Is the curve nonlinear? **Explain why.**




Yes, the curve is nonlinear because the two modes have independent energy budgets. Any excitation of the second mode, positive or negative, is energy that adds to the constant energy in the first mode. The curve has a minimum at S = 0 and increases with $S^2$.

e. Surface fluxes are approximately proportional to surface wind speed. **Plot** the domain-averaged surface wind speed versus S for values of S in [-0.5,0.5]. Is the curve nonlinear? **Discuss** the implications for tropical cyclogenesis, in terms of convective heating profiles and their dependence on low-level rain evaporation and downdrafts.




Yes, the curve is nonlinear. The second mode just adds energy, based on what the value of the stratiform fraction S, to the first mode. The surface wind is weaker when S is stronger, because a strong stratiform mode cools and creates divergence at shallow levels, which acts against the deep convective, cyclonic mode.

Thus, the phenomenon of rain evaporation / downdrafts / stratiform precipitation causes reduced surface fluxes, which would tend to interfere with the vortex developing into a tropical cyclone through self-induced surface flux enhancements.